White Paper

Operations Research & Artificial Intelligence Applications in Mobile Broadband Networks

Introduction

Rapid evolution of wirless technology, such as HSPA and LTE, provides increased capacity and speed to support mobile broadband Internet services, allowing wireless operators to create successful business models for new sources of revenue, by delivering a broad portfolio of high quality IP services and applications for customers who are always on the move. Meanwhile, the exponential mobile data traffic growth generated by proliferation of smart phones, such as iPhone and Blackberry and their associated applications, in conjunction with uncapped all-you-can-eat data service plans, has resulted in an explosion in bandwidth consumption and capacity drain to network resources, causing numerous network performance issues, such as under provisioning of network capacity, denial of network services, and unbudgeted emergency deployment of incremental equipment, all of which have tramadously negative impact on end-user experiences.

Building a quality network to ensure a growth in revenues that is tied to the successful delivery of mobile IP services, involves analyzing traffic that is highly sporadic in nature and that also varies geographically by time of day. As the demand for mobile broadband services increase exponentially, it is easy to see that wireless operators need fast, reliable methods for modeling and predicting the impact of mobile broadband traffic on the design and configuration of their networks as it materializes. In addition to this, ‘user mobility’ incurs a considerable management overhead or ‘tax’ on the network that reduces its capacity to support revenue earning services and adds another layer of complexity to the network design process.

In order to establish the fast, reliable predicting and modeling capability, it is imperative to adopt more sophisticated mathematical modeling methodologies, such as many techniques in Operations Research (OR) and Artificial Intelligence (AI), and apply them in mobile broadband network planning and optimization processes.

While Operations Research emphasizes optimizing organizational and system performance using advanced analytical methods to help make better decisions, Artificial Intelligence involves design of systems that are able to learn, perceiving their environment and taking actions that maximize their chances of success. In this paper we discuss a number of OR and AI applications in mobile broadband networks and show how sophisticated mathematical modeling can help wireless operators to minimize risk and maximize return of investment.

Data Mining Applications

Wireless operators make many business and engineering decisions depending upon customer and network reports, generated based on actual network measurements, inventory database and customer interactive database. However, those databases are vast in size with numerous errors, possibly caused by human mistakes and system deficits. While the vast database size makes it hard to extract exactly the information the wireless operators want, the errors in database often mislead them to bad decisions in terms of return of investment.

Data mining is branch of Artificial Intelligence, focusing on the process of extracting pattern from vast amount of data, with techniques that transform these data into information. Data mining applications in mobile broadband networks includes generating reports that displays data patterns (information) from vast amount of data, filling in missing data and replacing bad measurements using the recognized data pattern based on the historical data. The recognized data patterns can also be used for signaling possible equipment changes and

abnormal network conditions, helping operators to better manage their networks. For instance, using data mining techniques, the system is able to detect measurement errors in the database and network condition changes, as illustrated in *Figure 1*.

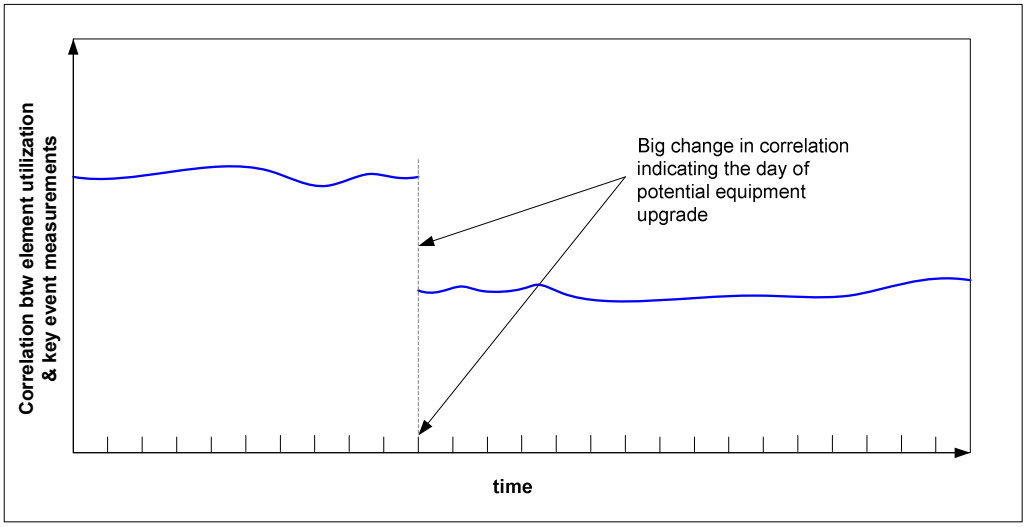

Figure 1: Automatically Detect Measurement Errors and Network Changes

Equipment Capacity Modeling

Currently, wireless operators heavily rely on their equipment vendors to provide them the equipment capacity numbers. Those numbers are usually impractical because they depend upon specific call profiles unseen in the real world. The inaccuracy of equipment capacity often leads the operators to under-engineer their networks, causing network performance issues, or to over-engineer their networks, increasing network costs. Thus, accurately modeling equipment capacity is critical in planning and managing mobile broadband networks.

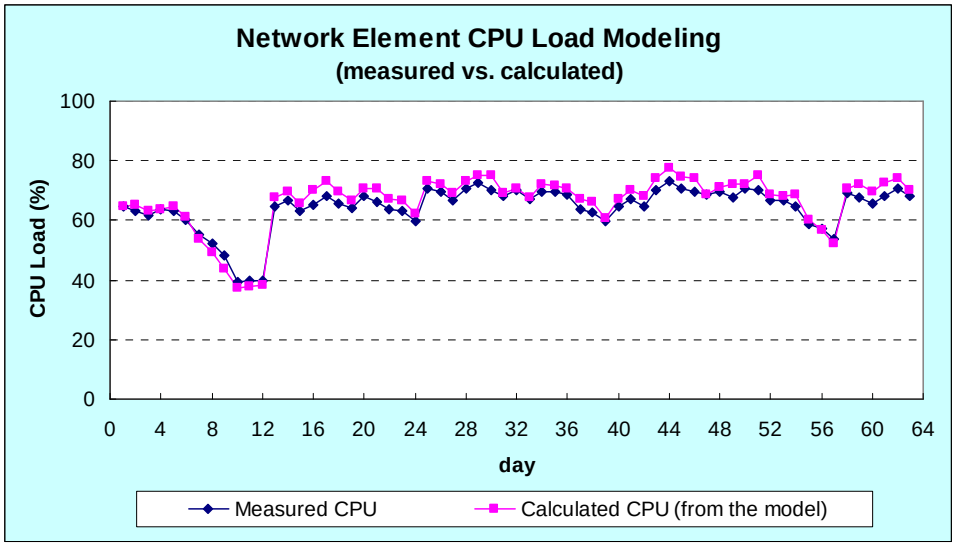

Figure 2: CPU Modeling using learning algorithms

As a branch of Artificial Intelligence, machine learning is concerned with the design and development of algorithm that allow computers to change behavior based on data. It automatically learns to recognize complex patterns and make intelligent decisions based on historical data. For instance, with the rapid evolution of mobile broadband networks, there is a drastic increase in transaction processing, such as CPU load and SS7 signaling, on network elements. Learning algorithms are developed for building the true CPU capacity models for different types of vendor equipment that characterize the correlations between CPU load and transaction related network events based on the historical measurement data. *Figure 2* shows how accurate a CPU model using learning algorithms is comparing to the measured CPU load. Those accurate CPU capacity models can be then used in capacity engineering and planning.

Cost and Inventory Management

Cost and inventory management techniques in Operations Research are often applied in various fields to minimize the inventory and cost while maintaining certain level of customer services. Sophisticated algorithms are developed to balace the need for product availability against the need for minimizing equipment holding and handling cost.

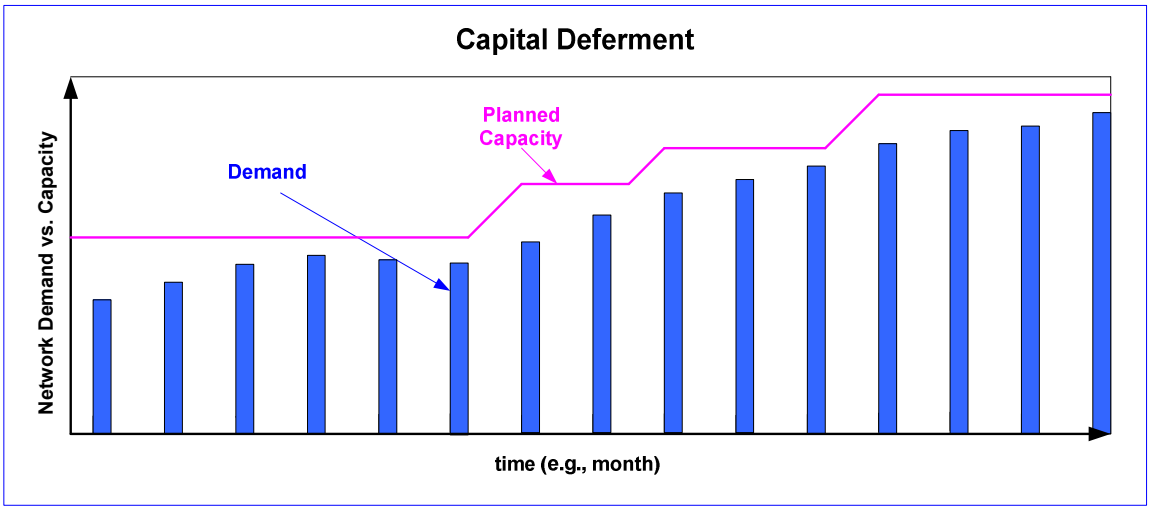

Figure 3: Capital Deferment using "just-in-time" Deployment

As the demand for mobile broadband services increase exponentially, network cost can skyrocket with the equipment is needed to support the traffic growth. Thus, it is essential for wireless operators to employ just-in-time deployment using cost and inventory management techniques, as showed in *Figure 3*, balancing the need for network capacity against the need for minimizing the cost of equipment deployment and upgrades.

Network Configuration Optimizations

Many wireless operators are in a reactive mode when determining network equipment deployment with little considerations of network-wide equipment capacity. They tend to deploy more equipment than needed. While some network elements are overloaded, others may be under-utilized, causing low ROI on those elements. For effective utilization of network equipment, holistic approaches must be considered in equipment purchase and deplouments. The loads among network elements need to be balanced via element-serving are design to maximize the network-wide equipment capacity as illustrated in *Figure 4*.

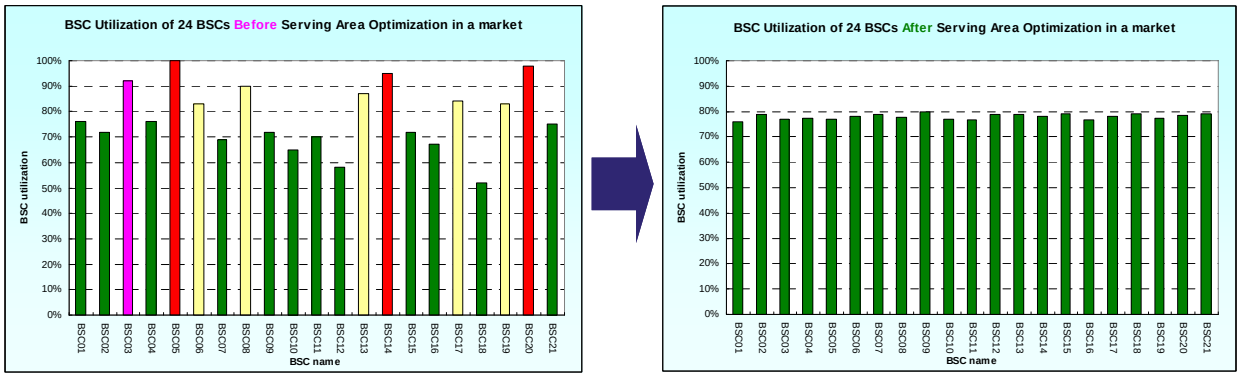

Figure 4: Maximize Overall Source Capacity through Element Load Balance

The key characteristic of wireless networks is its mobility services to subscribers. Yet, the wireless revenues are generated through voice and packet data services, not directly from mobility services. While mobility services do not directly generate revenues, they do consume network resources, including network equipment capacity. In a poorly designed network, considerable amount of network resources are used for mobility management, taking some resources away from revenue generation.

Mobility across borders of the network's serving areas consumes more network resource than mobility within serving areas. *Figure 5* shows the correlation between network resource usage and mobility across serving area borders. When the number of inter-MSC handovers is minimized, SS7 link usage on the MSC goes down. The saved SS7 link resources can be used for handling voice traffic, generating more revenue for wireless operators.

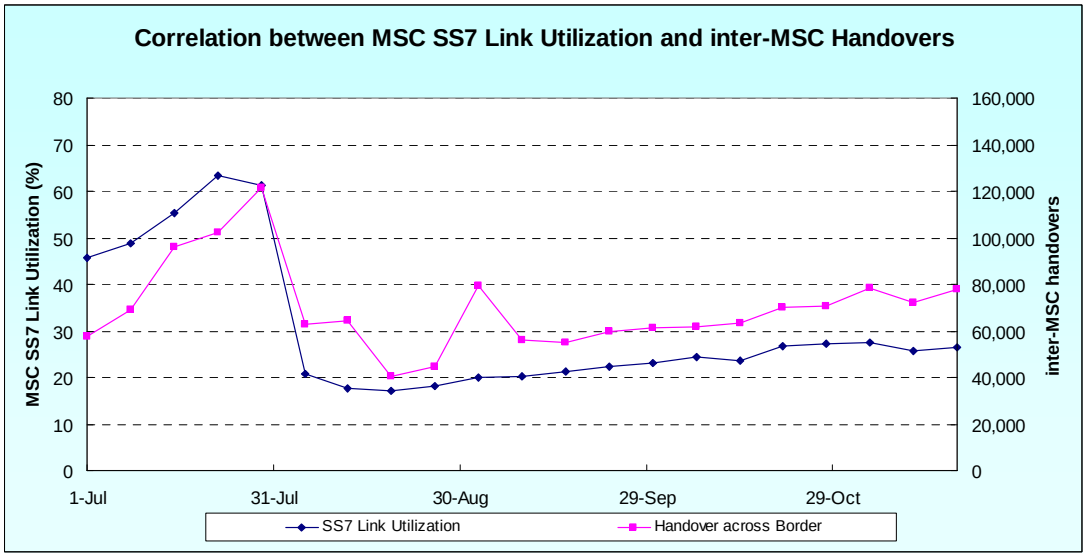

Figure 5: Increase Element Capacity by Reducing Inter-system Mobility

High mobility across serving area borders also compromises service quality. Thus, serving areas should be optimally designed so that the load on the equipment is balanced across the network while mobility across serving area borders is kept to a minimum.

To maximize revenue with the lowest possible CAPEX spending, optimization methodologies must be applied to wireless network designs. Optimal serving area designs maximize network

revenues for operators' CAPEX spending, and improve network service quality and reduce subscriber churn rate, which could provide wireless operators over a billion dollars in CAPEX savings and additional revenue generation.

Network Re-home Scheduling

Many Network re-home process could be extensive and not easy if poorly planned. Some of network equipment may hit their capacity limits because of re-shoveling of the sites, causing unnecessary expense on revised re-homes. High equipment load may require emergency additional equipment deployment, costing operators more in CAPEX and OPEX. During the site re-shoveling, bad serving area borders may be created, resulting in higher call drop rate and higher load on network equipment. High call drop rates cause subscriber churns and loss of revenue to operators. Revised re-homes increase re-home cost, adding more unnecessary cost to OPEX. Poor project planning also often results in project delays, which cause more in operators' OPEX.

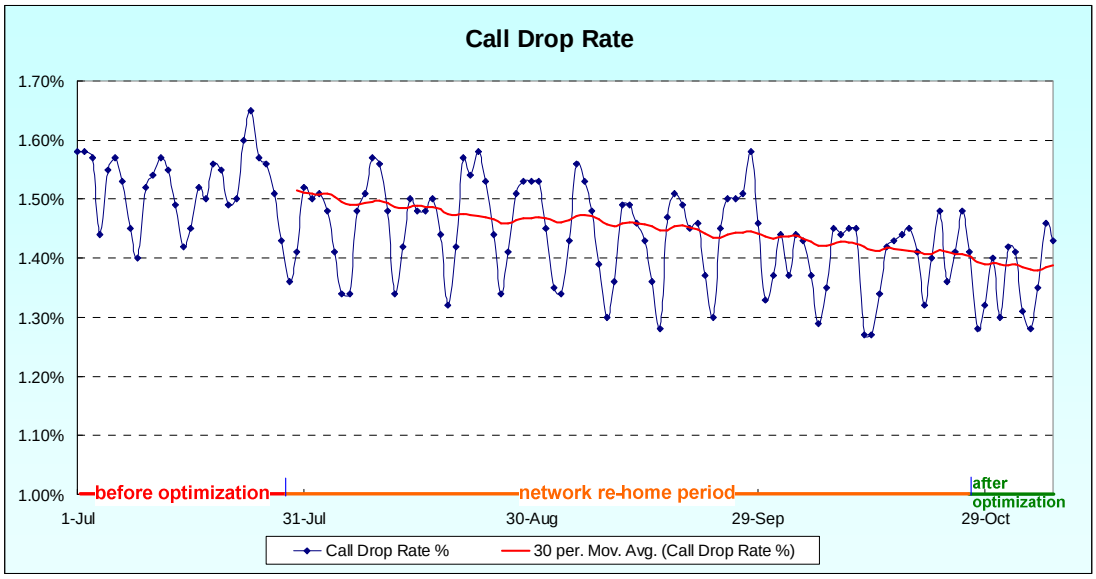

Figure 6: Call Drop Rate Before, During and After Optimization

Network re-home process should be carefully planned using optimization algorithms to achieve smooth network topology migrations, ensure good service quality to subscribers, and minimize the number of revised re-homes. *Figure 6* shows call drop rate changes throughout a network re-home period by implementing network re-homing optimization in a market, which clearly illustrates the network service quality improvements provided by serving area optimization and network re-home optimization. *Figure 7* illustrates that re-home sequencing algorithms ensure the element loads are under control during element re-home period.

In addition to the financial benefits, a detailed re-home sequencing and schedule can be generated by the optimization process and be provided to the field engineers for re-home implementations, helping operators on project management and inter-departmental collaborations.

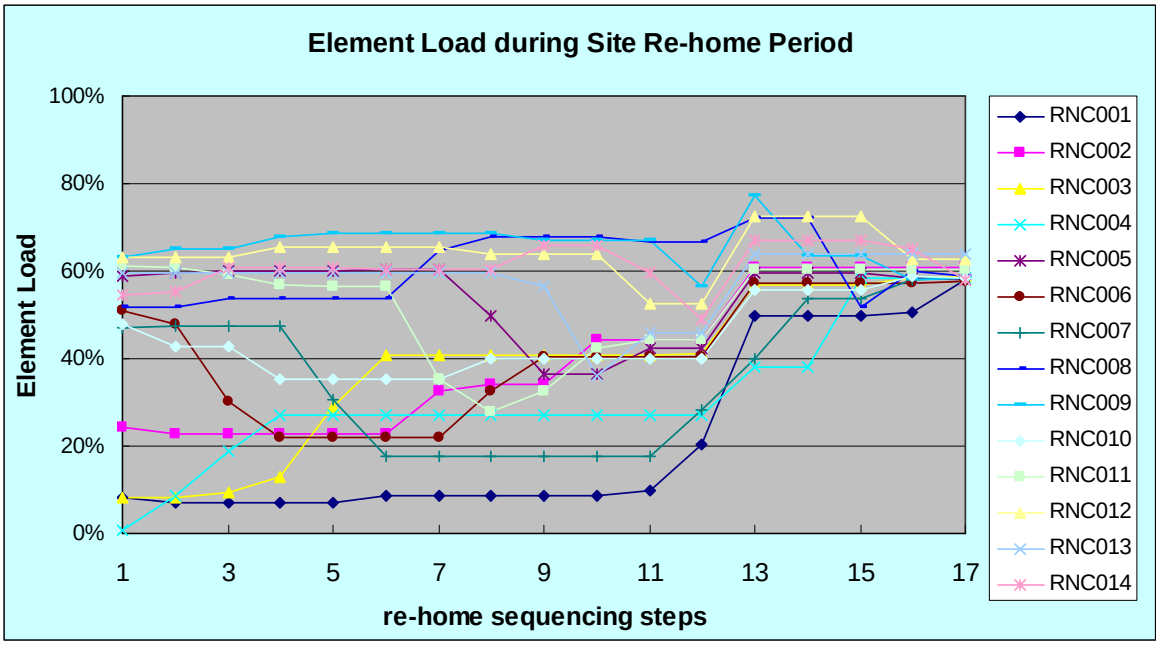

Figure 7: Avoid Element Overload during Re-home Period

Conclusion

By leveraging machine learning to understand in real time the impact of mobile IP demand on network design; and running optimization algorithms that evaluate all possible configurations of the network ahead of time; a new generation of wireless network planning tools can be used to dramatically simplify the task of network engineering – And to diagnose and resolve potentially catastrophic problems, before they have even happened.

In this way, mobile operators can dramatically reduce the risk associated with network failures and potential under or over investment – Helping them make the best-possible investments as their networks evolve over time, achieving maximum revenue potential from these investments and at the same time delivering the best end-user experience possible.

Success means leveraging cutting edge design tools to help streamline and maximize the efficiency of the design process – Ensuring maximum design precision that keeps pace with emerging demand, minimal time to market for the implementation of these new designs and lean equipment provisioning that minimizes the total cost of network ownership.

Cerion Optimization Services, Inc. is a wireless-focused solution provider, optimizing wireless network performance and extracting hidden financial value within the wireless network. One of our visions when we founded Cerion was to devise solutions that would help networks to become self engineering. Now leveraging a combination of our own ideas and those of the master mathematicians of the past we are making this a reality – Helping our customers reduce costs, optimize revenue and minimize risk as their networks transition to deliver the broadband mobile Internet.

To learn more about Cerion Optimization Services, Inc. and our solutions and services visit www.cerioninc.com or call 1-214-619-8000.